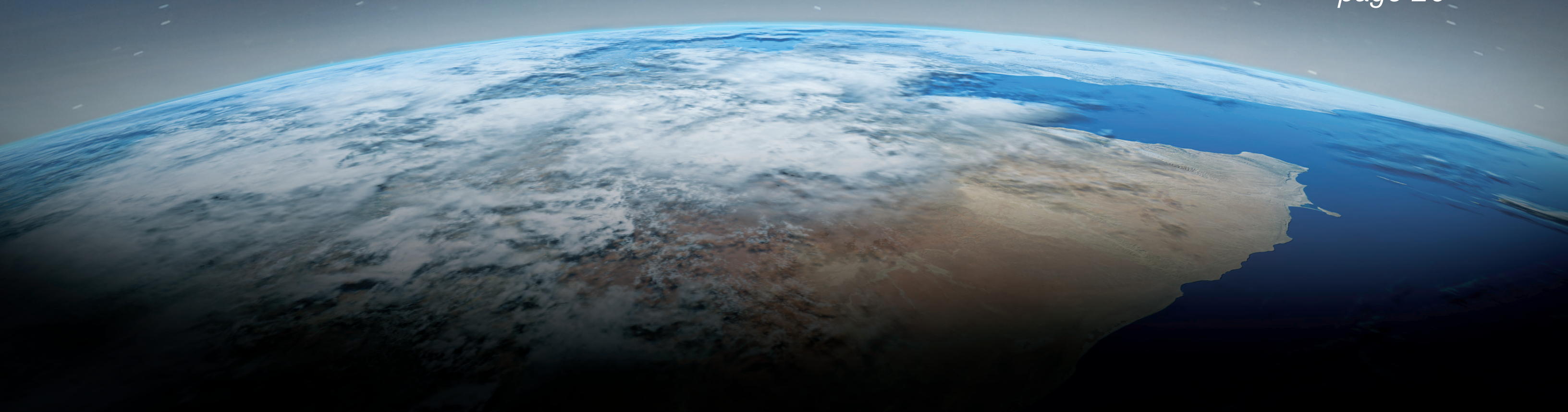
Museum of Science

DESTINATION MARS

THE NEW FRONTIER

AN EDUCATOR'S GUIDE



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This material is based upon work supported by NASA under grant number NNX16AM21G. Any opinions, findings, and conclusions or recommendations expressed are those of the Museum of Science, Boston and do not necessarily reflect the views of the National Aeronautics and Space Administration (NASA).

How to Use This Guide

This guide is a supplement for teachers bringing their students to the Planetarium show *Destination Mars: The New Frontier* at the Museum of Science, Boston.

- The suggested age range for this show is grade 4 – 12.
- Related Museum programming and online learning tools are included in this guide.
- **Bolded words** are defined further in the glossary (pages 20).

Contact Information

- For questions regarding *Destination Mars: The New Frontier*, email schoolplanetarium@mos.org.
- For general field trip planning resources, visit mos.org/educators.
- For school group reservations, call Science Central, open daily 9:00 a.m. – 5:00 p.m. at 617-723-2500.

Credits

Destination Mars: The New Frontier was produced by the Museum of Science, Boston (mos.org). This guide was developed by the Charles Hayden Planetarium staff.

ABOUT THE CHARLES HAYDEN PLANETARIUM

THE EXPERIENCE

The Charles Hayden Planetarium at the Museum of Science offers visitors of all ages an immersive space exploration experience. Detailed and accurate star maps and digital video are projected onto the 57-foot-wide dome overhead, allowing students to appreciate the vastness of space in three dimensions.

ACCESSIBILITY

The Charles Hayden Planetarium is wheelchair accessible. Show scripts for *Destination Mars: The New Frontier* are available upon request. Please contact schoolplanetarium@mos.org with questions about further accessibility needs, including assistive-listening devices and closed-captioning for the hearing impaired.

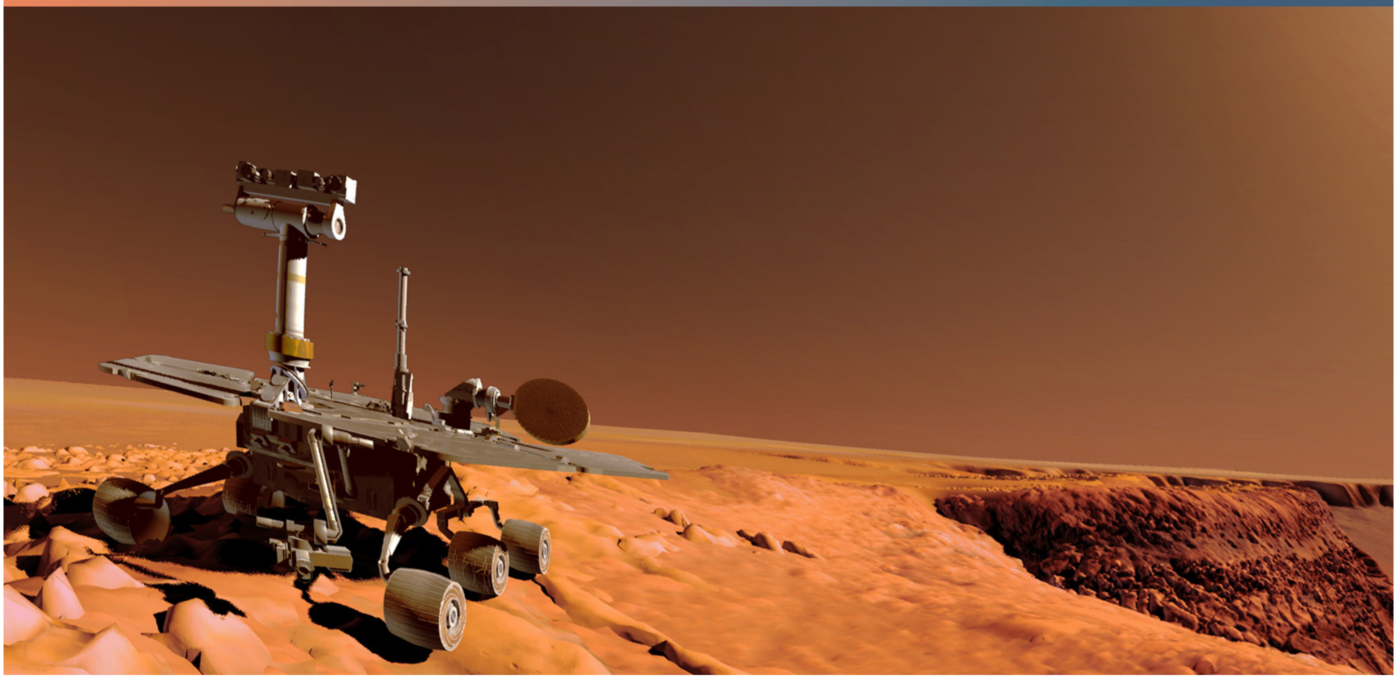


Photo couretesy of NASA/JPL/Cornell University, Maas Digital LLC

Mars. Our neighboring planet has captured the human imagination for centuries. We've watched it with our eyes, through our telescopes, and with the cameras of our robotic explorers. Today we have set ourselves a more difficult task: getting humans to the Red Planet.

Our journey begins on the surface of Mars, watching the sunrise over its rust-colored canyons and craters as we consider modern-day Mars. Then, instantly, we are transported back three billion years, to look at Mars as it once was—a warm, wet, temperate world covered with lakes and rivers and blue skies. As we fly over a braided riverbed, we see the water vanish and the skies lighten as we return to modern Mars, flying past the Opportunity Rover as we take off to view the planet from space.

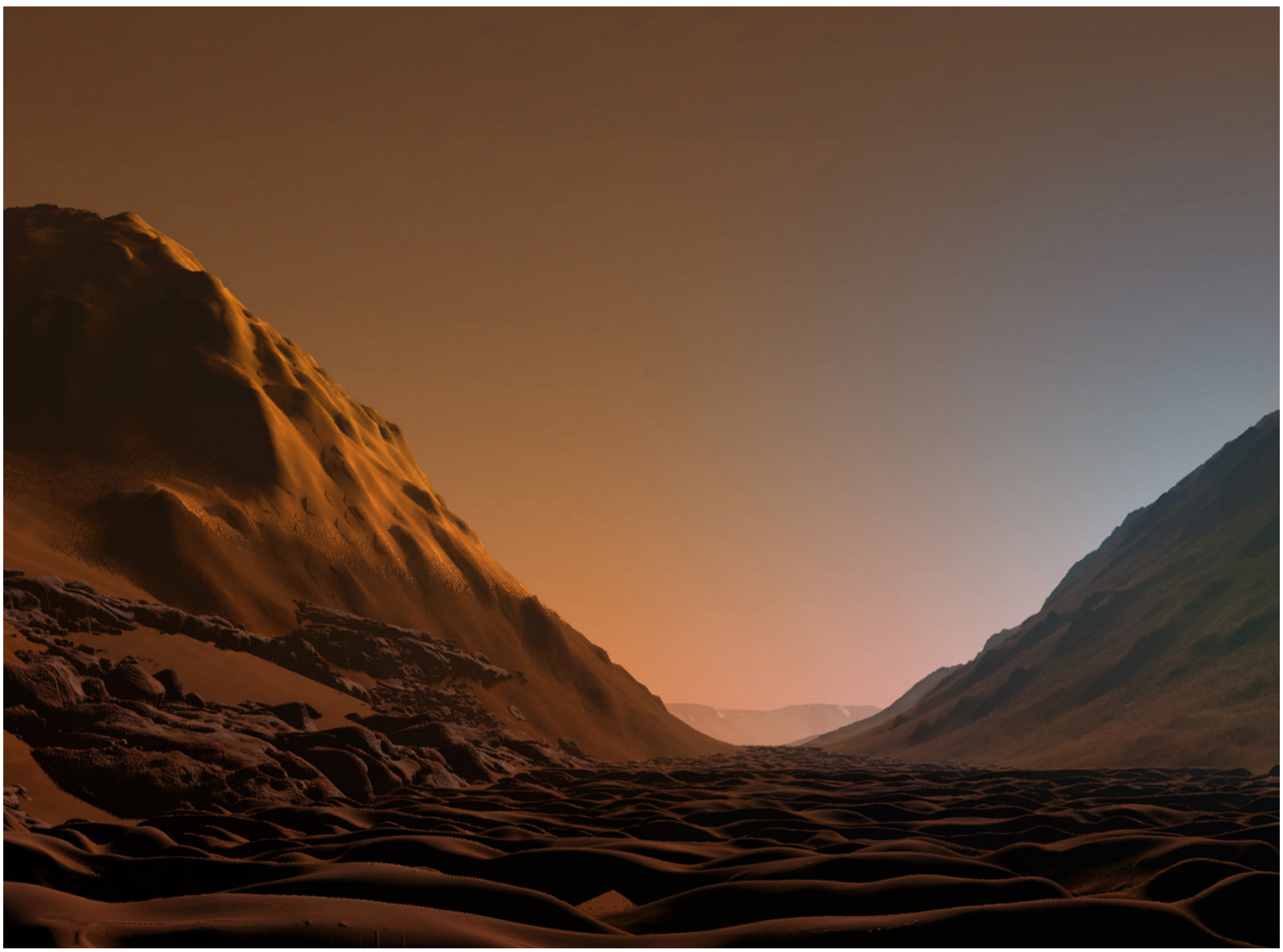
To discuss some of the challenges of getting to Mars, we first take a look at some of the challenges we've already overcome in space. We return home to Earth orbit for a flight around and through the International Space Station (ISS), discussing the building of the Station and its contributions to modern science.

But while the ISS is an important foundation, it's time to look at what comes next, as we exit the station through its cupola window, descending to Earth in the wake of a SpaceX Falcon rocket heading for a landing at Kennedy Space Center. From there, we soar over the Space Center to the incredibly huge Vehicle Assembly Building, one of the largest buildings in the world, to see the construction of NASA's next great rocket, the Space Launch System (SLS).

Over 300 feet long, the SLS is designed to carry the four-person Orion space capsule out of Earth orbit, to the Moon and beyond. As we fly up the side of the rocket to the capsule, we find ourselves suddenly in space, riding along on Orion's planned first mission with SLS, called Exploration Mission-1 (EM-1), which will have no astronauts aboard and which will carry Orion all the way to the Moon.

Future Orion missions may build a new space station in lunar orbit, which can serve as a refueling station for eventual missions to Mars.

We now imagine what such a mission might look like, listening to the personal log of an astronaut as she narrates parts of her long journey through space to Martian orbit, and from there down to the surface where she looks out on humanity's new frontier outpost and her temporary home: Mars.



Next Generation Science Standards

PERFORMANCE EXPECTATIONS	
3-5-ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS1-2	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
MS-ESS1-3	Analyze and interpret data to determine scale properties of objects in the solar system.
MS-ETS1-4	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
HS-ETS1-1	Analyze a major global challenge to specify a design problem that can be improved. Determine necessary qualitative and quantitative criteria and constraints for solutions, including any set by society.
HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Massachusetts Science and Technology/Engineering Standards (2016)

STANDARDS	
1.K-2-ETS1-1	Ask questions, make observations, and gather information about a situation people want to change that can be solved by developing or improving an object or tool.
3.3-5-ETS1-1	Define a simple design problem that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost that a potential solution must meet.
4.3-5-ETS1-5 (MA)	Evaluate relevant design features that must be considered in building a model or prototype of a solution to a given design problem.
5.3-5-ETS3-1 (MA)	Use informational text to provide examples of improvements to existing technologies (innovations) and the development of new technologies (inventions). Recognize that technology is any modification of the natural or designed world done to fulfill human needs or wants.
6.MS-ETS1-5 (MA)	Create visual representations of solutions to a design problem. Accurately interpret and apply scale and proportion to visual representations.
HS-ETS1-1	Analyze a major global challenge to specify a design problem that can be improved. Determine necessary qualitative and quantitative criteria and constraints for solutions, including any requirements set by society.
HS-ETS1-2	Break a complex real-world problem into smaller, more manageable problems that each can be solved using scientific and engineering principles.

Earth vs Mars: A Comparison

	EARTH	MARS
Average Distance from Sun	92,955,902 miles (1 au)	141,634,900 miles (1.5 au)
Radius	3,958.8 miles	2,106.1 miles
Length of Year	365.26 Earth days	686.97 Earth days
Axial Tilt	23.44˚	25.19˚
Average Daytime Temperature	58.7˚F (14.9˚C)	-82˚F (-63˚C)
Number of Moons	1	2
Length of Day	24h	24h 37m 22s
Gravitational Force at Surface	1 g	0.376 g
Average Air Pressure at Surface	101.3 kPa (1 atm)	0.63 kPa (0.00628 atm)
Average Atmospheric Composition	78.08% Nitrogen 20.95% Oxygen	95.97% Carbon Dioxide


Photo couretesy of NASA/Apollo 17 crew

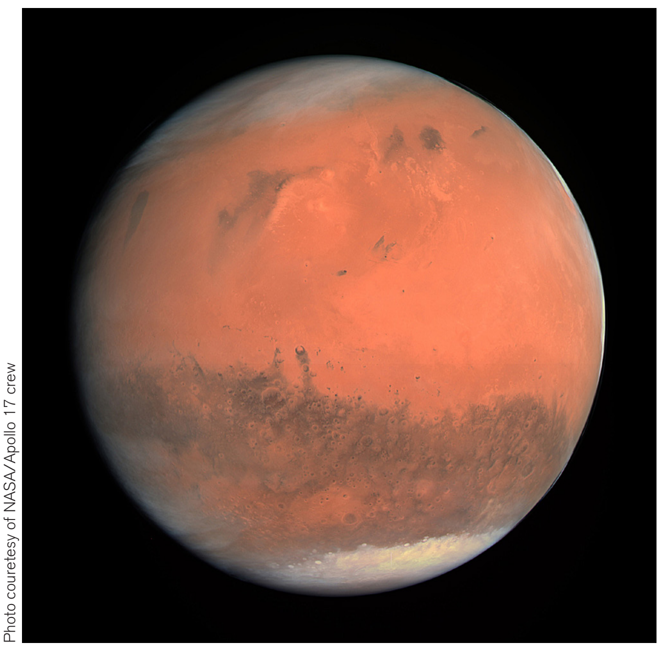


Photo couretesy of Wikimedia Commons

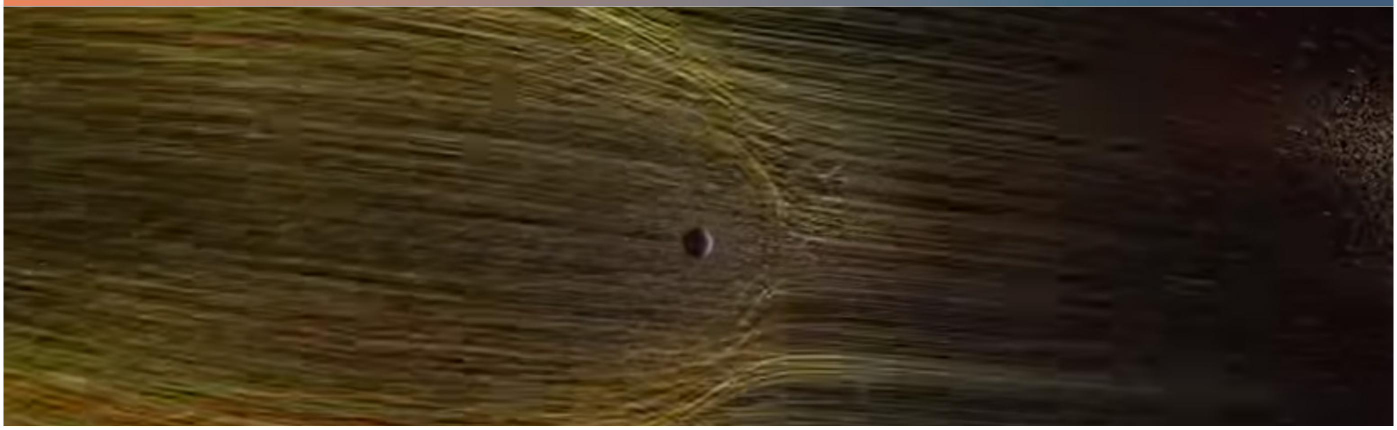


Photo courtesy of NASA/Goddard Space Flight Center Scientific Visualization Studio

A Drying Planet

From a human perspective, Mars today is a hostile world. It has an extremely thin atmosphere, about 1/100th the thickness of Earth's. Its average daytime temperature is well below freezing. It is not geologically (or **areologically**) active, so there is no volcanic activity or movements of the crust. There is no magnetic field surrounding Mars as there is around Earth, so there is no protection from the particles streaming off of the Sun that we call the **solar wind** (it also means a compass will not work on Mars). The planet is excessively arid. Water, essential to life as we know it, can be found frozen, along with carbon dioxide, at the two polar ice caps, and there are also large deposits of frozen water under the ground as well. However, the incredibly low temperatures and extremely low air pressure at the surface ensure that liquid water cannot last for very long before either freezing or vaporizing.

It appears now that this was not always the case. Evidence from our Martian **orbiters**, **landers**, and **rovers** has shown that, billions of years ago, Mars had a wet, temperate climate, and there are ample signs of rivers and lakes on the surface, as well as possibly a small ocean. So what happened?

Magnetism

Billions of years ago, Mars's internal structure had a lot more in common with Earth's. Despite being approximately 4.5 billion years old, Earth is still cooling down from its molten, fiery formation. A lot of this residual heat is in the core, which is made of liquid iron. This hot core drives volcanic and tectonic activities on the surface. It also generates Earth's **magnetic field**.

We use Earth's magnetic field in navigation, since it is what directs a compass to point north, but it has a far more vital, if subtle, role in everyday life. Our Sun is constantly shedding a stream of charged particles known as the solar wind, which could have potentially damaging effects on Earth's surface and atmosphere. Fortunately for us, Earth's magnetic field acts as a shield, blocking most of the effects of this wind, deflecting the charged particles out into space and occasionally directing some toward Earth's poles, where they interact with the atmosphere to light up the sky as the Northern and Southern Lights.

Billions of years ago, Mars was in a similar state, and looked very different than it does today. It had a much thicker atmosphere, which was often augmented by massive eruptions from a series of highly active volcanoes whose extinct humps are still visible on the surface today. The largest volcano in the solar system, Olympus Mons, over twice the height of Mount Everest, was among these energetic mountains.

The thicker atmosphere acted as a blanket to trap warmth from the Sun, much as Earth's does, and left the surface of Mars a significantly warmer place than we find it today. It was warm enough to maintain the rivers and lakes of which our spacecraft have found remnants, and may have been able to support what we would recognize as life. As of this writing, no evidence has been found of life on Mars, but astronomers are increasingly confident the required conditions did once exist there.

Its moving liquid iron core also provided a younger Mars with the magnetic protection Earth enjoys today. However, as a much smaller object than Earth, Mars cooled from its formation much, *much* more quickly. Just like cooling liquid water will turn it solid, the cooling of Mars's core turned it from a maelstrom of liquid iron to a hard lump of solid iron. Solid iron does not generate a magnetic field or drive volcanic activity.

Thinning Air

Losing the supplemental gases provided by Mars's volcanoes along with the shield against the solar wind was a double whammy from which Mars's atmosphere never recovered. With nothing to block it, the force of the solar wind began to strip air from Mars, sending it out into space. Without volcanic activity to help replace the lost gases, Mars's atmosphere quickly became the thin shell of air we see around modern Mars.

A thin atmosphere, like a thin blanket, is bad at trapping heat, and the surface of Mars rapidly morphed into the cold, dry desert of today. It lost its liquid water into ice deposits and into vapor that joined the gases being stripped from the air, leaving us the arid world we recognize as the Red Planet.

Ancient Observations

Mars is visible to the naked eye as a bright star-like object with a distinctively reddish color (Mars's nickname, the Red Planet, comes from the large amounts of oxidized iron, also known as rust, found in its soil, giving the world its distinctive color). As a naked-eye object, Mars has been studied since humans first looked up at the sky.

Surviving observations of Mars date back to Egyptian astronomy of the 2nd millennium BCE, where Mars can be found on star charts and painted on the walls of tombs. Ancient records also survive from Babylon, China, and Greece.

Its obvious red tint led many ancient cultures to give the planet names associated with war, blood, or fire, including the name we currently use for it—Mars was the Roman representation of Ares, the Greek god of war.

Telescopes and Canals

The advent of the telescope as an astronomical tool led to a new era of Martian observations, as surface features became visible through improved instruments. The first map of Mars, a very rough representation, was published in 1840. In 1877, the Italian astronomer Giovanni Schiaparelli recorded what he believed to be straight lines on the surface (later revealed to be a false observation) which he called channels, or

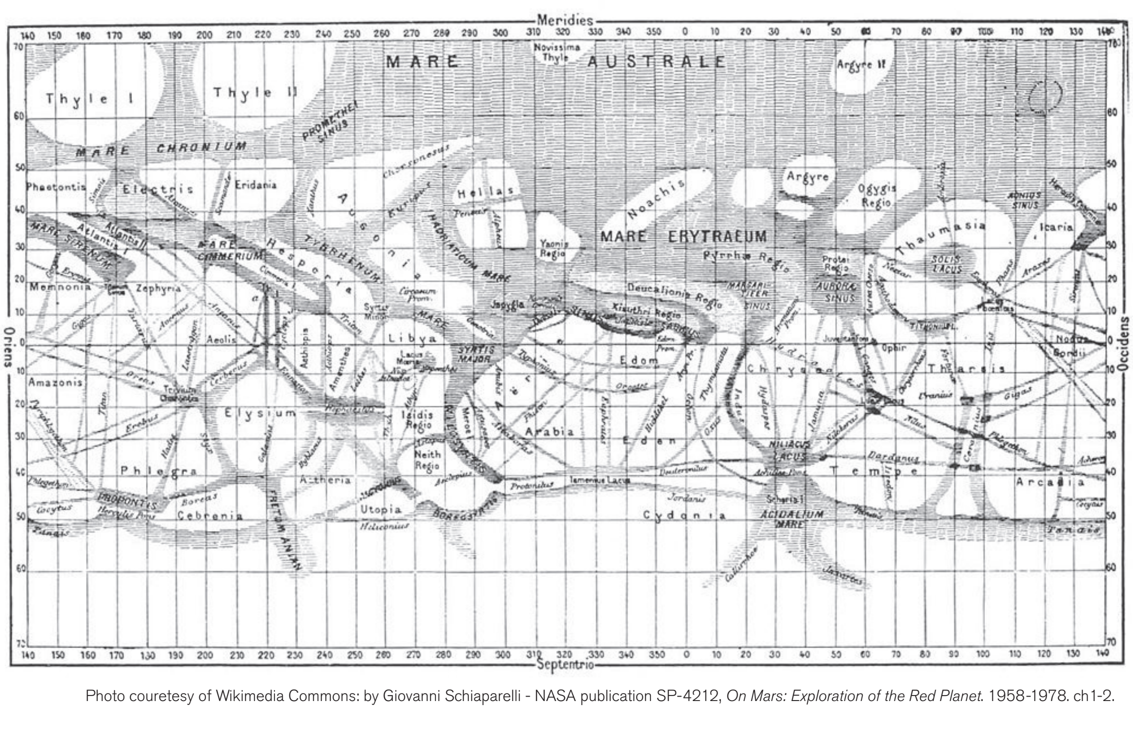


Photo couretesy of Wikimedia Commons: by Giovanni Schiaparelli - NASA publication SP-4212, *On Mars: Exploration of the Red Planet*. 1958-1978. ch1-2.

canali, in Italian. This was improperly translated into English as "canals," giving rise to the belief that artificial structures had been sighted on Mars, and fueling the idea that a civilization might exist on our neighboring planet.

As telescopic observations continued to improve in the early half of the 20th century, the lack of obvious artificial structures largely set the idea of a Martian civilization aside, but it was not until the 1960s that we got to see Mars up close.

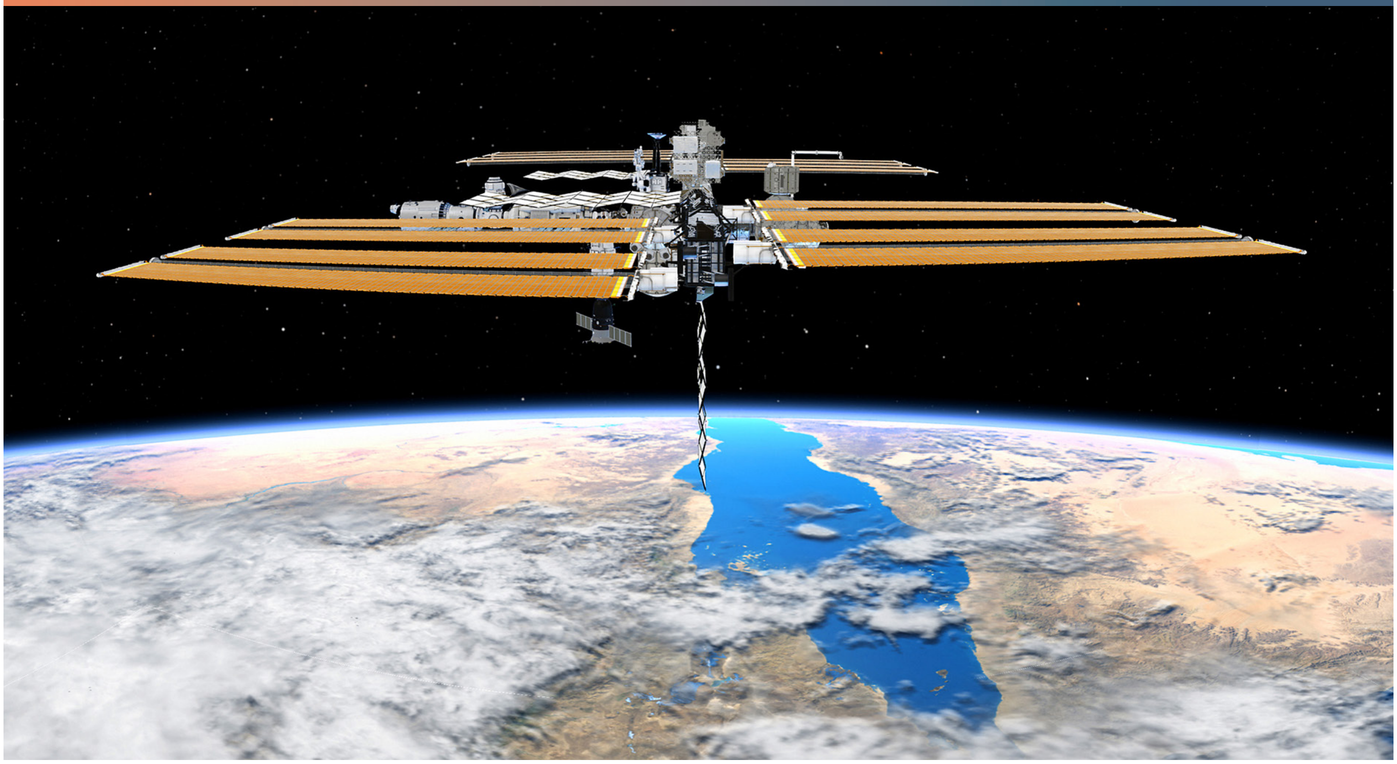
Photo couretesy of NASA/JPL

The Age of Spacecraft

After many failed attempts by both the Soviet Union and NASA to send a spacecraft to Mars, the first successful Martian **flyby** took place on July 15, 1965, by a NASA spacecraft named Mariner 4. This flyby not only removed forever the notion of a civilization on Mars, it also allowed the first up-close study of our neighbor.

Since Mariner 4, Mars has proven to be an inviting target. Mars is the easiest planet to get a spacecraft to. It is relatively close, so the travel times of these spacecraft are measured in months, rather than years. Mars is in a good position relative to Earth for a **launch window** to open every two years or so, allowing for frequent missions. And Mars is close enough to the Sun that spacecraft can use solar power, rather than the more expensive and difficult to obtain nuclear fuel that is required for spacecraft heading to the outer Solar system.

Despite these advantages, missions have a rough history when it comes to getting to Mars. Nearly 50 Martian missions have reached the launchpad, and nearly half of those have failed, whether at launch, in flight, or upon arrival. As of 2019, NASA remains the only space agency to have successfully landed a spacecraft on the surface of Mars, although several others have found success in their orbital spacecraft.



The International Space Station is one of mankind's greatest engineering achievements. It is an orbiting laboratory, continuously inhabited since 2000. Designed primarily to support scientific research that requires the microgravity environment of space, since 2010 it has also been used for commercial, diplomatic, and educational missions.

The ISS is also a miracle of international cooperation. Its existence is the result of a joint effort, both in building and staffing the station, of five space agencies representing 16 different countries on three continents.

Today the ISS continues its mission as an orbital laboratory, with current plans to keep it operational through at least 2024. Staffed with a crew complement drawn from the astronaut corps of the participating countries, the station continues to be added to and updated to this day.

Having a base of operations in orbit allows us to test the effects of long-duration space flight like that required for a trip to Mars on the human body. Between March 27, 2015 and March 2, 2016, US astronaut Scott Kelly and Russian cosmonaut Mikhail Kornienko set a new endurance record for living on the ISS. The two men spent 342 days on the station to determine the effect of almost a year in space on a human's physical and mental health. The results of this experiment will play a large part in research focusing on sending people on the long trip to and from Mars.

ISS Specifications

First module launched	Zarya module, launched November 20, 1998
Length	239 feet
Width	356 feet
Full staff	6
Length of orbit	93 minutes
Orbits per day	15.5
Average height of orbit	250 miles
Participating countries	United States, Russia, Japan, Canada, Austria, Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom

Photo couretesy of NASA/JSC

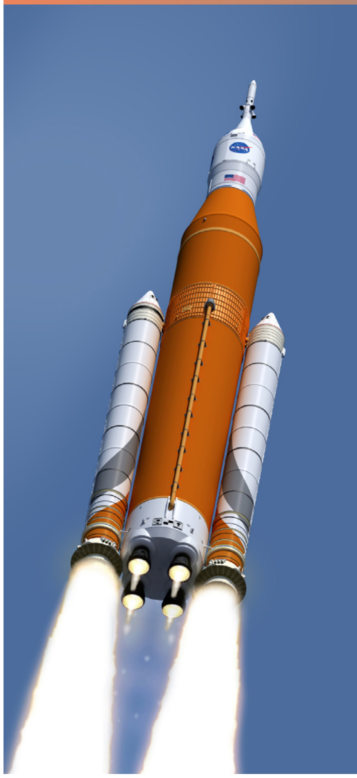
Mars Exploration Today

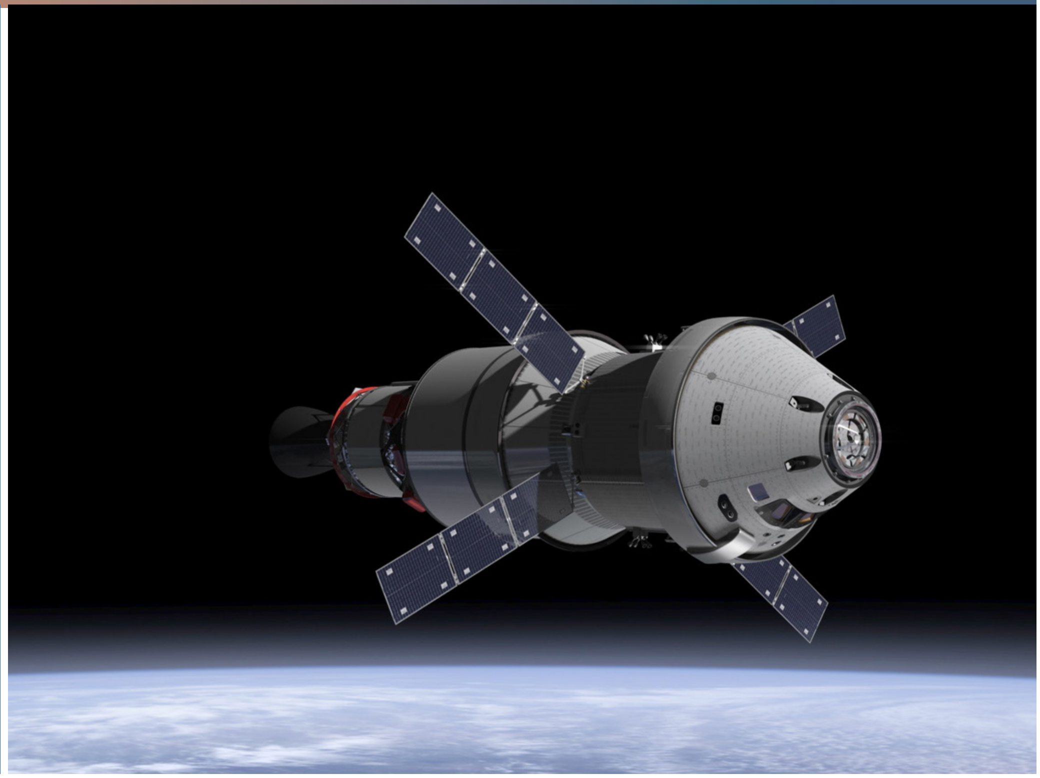
As of this writing in November 2018, there are nine missions successfully operating on or around Mars. Some of these are among the longest continuously operating spacecraft found anywhere in the Solar system.

MISSION	TYPE	MARS ARRIVAL DATE	OPERATING SPACE AGENCY
Mars Odyssey	Orbiter	October 24, 2001	NASA
Mars Express	Orbiter	December 25, 2003	European Space Agency
Opportunity	Rover	January 25, 2004	NASA
Mars Reconnaissance Orbiter	Orbiter	March 10, 2006	NASA
Curiosity	Rover	August 6, 2012	NASA
MAVEN	Orbiter	September 22, 2014	NASA
Mars Orbiter Mission	Orbiter	September 24, 2014	Indian Space Research Organisation
ExoMars Trace Gas Orbiter	Orbiter	October 19, 2016	European Space Agency/ Roscosmos (Russia)
InSight	Lander	November 26, 2018	NASA

Martian Future

Two more large rovers are currently scheduled for launch during the 2020 launch window, one from NASA and one from the European Space Agency. An additional two missions are on the docket representing the first Mars missions for the United Arab Emirates and China. A number of space agencies and private companies are making plans to put humans on Mars, both for exploration and, in the far future, eventual colonization. NASA currently has the goal of putting humans on Mars by the 2030s.





Photos couretesy of NASA

Mars may be nearby, astronomically speaking, and have a relatively pleasant surface compared to some of the other planets of our solar system, but that does not mean that getting there or surviving there will be easy tasks. Mars poses a number of challenges that will have to be overcome for anyone to get there and back safely.

Getting There

Even the process of getting off the Earth can prove to be a challenge. In order for a rocket to send a spacecraft to Mars (or to the Moon, or to anywhere beyond Earth orbit), it has to go faster than Earth's **escape velocity**, the speed at which it becomes possible to move beyond Earth's gravity. To reach escape velocity a rocket must carry a lot of fuel which, in turn, requires a larger rocket. A spacecraft that can sustain humans on a trip to Mars will also be very large and heavy, loaded down with the extras like air, water, and food that humans need and robotic explorers do not. The rocket must be able to lift this heavy payload, as well as its own load of fuel.

It is for missions like this that NASA is designing the Space Launch System (SLS), a rocket designed to send humans out of Earth orbit. Larger than any rocket in use today, the SLS will rival the Saturn V moon rocket in size, at roughly 350 feet tall. Exploratory Mission-1, the first test mission of the SLS with its specially designed space capsule, Orion, is due to take place in 2020 (without humans aboard).

Once the rocket is ready, the spacecraft that will hold the astronauts will need to be designed. Astronauts going to the Moon made due with a very small amount of space in the Apollo Command and Lunar Modules, but their trips lasted mere days. The outgoing trip to Mars will take months, and the astronauts will require more living space. The spacecraft will also need to carry air, food, and water for the journey. The ISS has made great strides in the science of recycling and conserving water and air, and has begun experiments allowing astronauts to grow their own food aboard, but the systems are not perfect.

The spacecraft will also need to protect the astronauts from radiation. A trip so far away from Earth will carry the astronauts out of the protective shield of Earth's magnetic field, exposing them directly to the harsh radiation from the Sun and space for months at minimum. All existing radiation shielding is heavy and cumbersome—both bad traits for a spacecraft to have. One solution may be to find a way to use the spacecraft's own water supply as a shield, by storing it between the spacecraft's outer skin and the astronauts' living spaces, forming a layer which will protect against some of the incoming radiation.

The radiation problem as yet has no perfect solution, but is under consideration, since it will form a serious obstacle to all interplanetary travel.

On the Surface

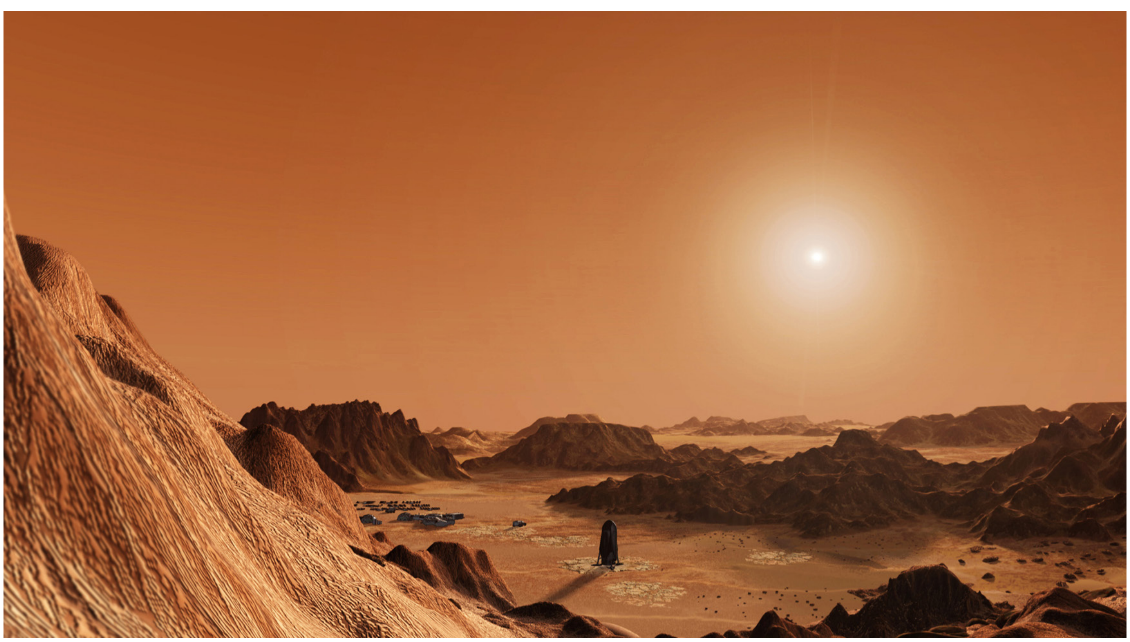
Once the astronauts reach Mars, they will have to make it safely to the surface. Landing gently on Mars poses a different challenge than landing on Earth or the Moon. Unlike the Moon, Mars has some atmosphere, so an approaching spacecraft cannot simply rely on rocket engines to slow its descent, the way the lunar landers did. And unlike Earth, Mars does not have a significantly dense enough atmosphere that friction and parachutes can be used to safely lower spacecraft to the ground, as returning moon missions did. Mars's atmosphere is thick enough that it cannot be ignored, but not thick enough to be very helpful in slowing down a spacecraft.

Methods pioneered by our robotic explorers may provide a solution. Smaller rovers and landers, such as the Spirit and Opportunity Rovers, have been partially slowed by parachutes and then allowed to bounce to the surface ensconced in a cocoon of airbags. This method might be used for smaller, less delicate payloads, like food supplies, which do not necessarily require a soft touchdown. Anything that requires a gentle landing, like humans, cannot use this method, and heavier payloads will burst the airbags.

For these larger and more fragile payloads, we may use a combination of parachutes and rockets, similar to that pioneered by the large, heavy Curiosity Rover in 2012. This rover slowed its descent first under a parachute, and then at a lower altitude used rockets to slow its speed enough that the rover itself made a successfully placid touchdown.

To make the long trip to Mars worthwhile, a human mission—after safely touching down—would likely stay on the surface for at least a month. Over the course of that month they will have the same sorts of needs they had on the way: food, air, water, and shelter—both from Mars's painfully cold and dry environment and the radiation against which Mars, with its lack of magnetic field, provides no protection. One solution to the radiation problem on the surface may be to build a shelter underground, allowing the soil and rock of Mars itself to act as a radiation shield.

A series of experiments in the arid, cold conditions found high on Hawaiian mountains have allowed humans to simulate living in Martian conditions. Those participating in these missions, called HI-SEAS (Hawaii Space Exploration Analog and Simulation) behave as though their enclosed habitats are on Mars itself—they live entirely off a pre-packed supply of food, water, and power and don spacesuits to exit the habitat. From experiments like this we are learning firsthand about some of the difficulties that will be faced by the first astronauts to work on Mars for real.



Getting Home

As of now, no space agency has plans to send humans to Mars permanently—all plans are to return these explorers to Earth. These astronauts will have to launch off the surface to return to their spacecraft. Mars's lesser gravity makes getting off the surface much easier than launching from Earth's, but still requires a heavy launch vehicle that must be safely brought to the surface in the first place. Such a vehicle may be sent to Mars well ahead of the astronauts and landed remotely.

Once in space, the astronauts will face much the same issues they faced on their way out, with the added psychological strain of having been away from home for a long period of time. Similar to the HI-SEAS missions, we have tested out conditions like these here on Earth before asking anyone to do it in space.

Between June 2010 and November 2011 the Mars500 experiment simulated a full 520-day Martian mission, with a crew of six staying in an enclosed space designed to look like a spacecraft, interrupted by a 30-day period in the middle on a simulated Martian surface. The results of this experiment help us understand the psychological effects on a human of spending such a long period in a confined space with only a few other people. These are the sorts of difficulties that will undoubtedly arise during the long journey to and from Mars.

Areologically: The Martian equivalent of "geologically." Since the "geo" in "geologically" translates to "Earth," technically speaking it only refers to activity on Earth itself. The corresponding term for Mars would be "areo," thus "areologically."

Escape Velocity: The speed at which an object must travel to escape the gravitational field of another larger object. For instance, a spacecraft seeking to counteract Earth's gravity to go to another place in the solar system (e.g., Mars) must reach a speed of over 25,000 mph, making this Earth's escape velocity.

Flyby: When a spacecraft does not slow down to enter orbit around a target, such as a planet or asteroid, but instead speeds past it. These short encounters still allow a passing spacecraft to perform significant scientific observations of the object it is flying past.

Lander: A spacecraft designed to make it to the surface of a solar system object, such as a planet or asteroid, and then remain in one spot, with no capability of changing its location.

Launch Window: Refers to the period of time in which a spacecraft can be launched and successfully reach its destination with the available resources onboard. Mars and Earth are near each other in space about every two years, which means every two years a Mars launch window opens, when a spacecraft can be launched from Earth and expect to arrive at Mars in less than a year. Typical travel time to Mars during these launch windows is around 6 – 10 months.

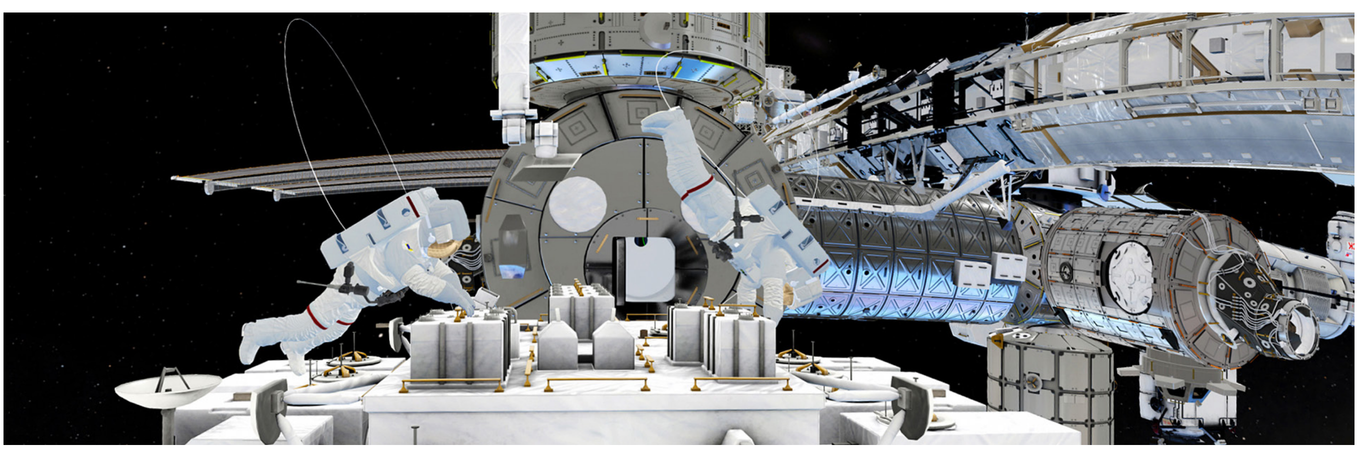
Magnetic Field: The area around a magnet in which other magnets, electrical currents, and charged particles will be affected by the magnetic force emitted by the original magnet. The moving liquid iron core of the Earth acts as a magnet, producing a magnetic field that surrounds the entire planet. This affects the magnetic needles of compasses (causing them to point north) and the charged particles of the solar wind, among other things.

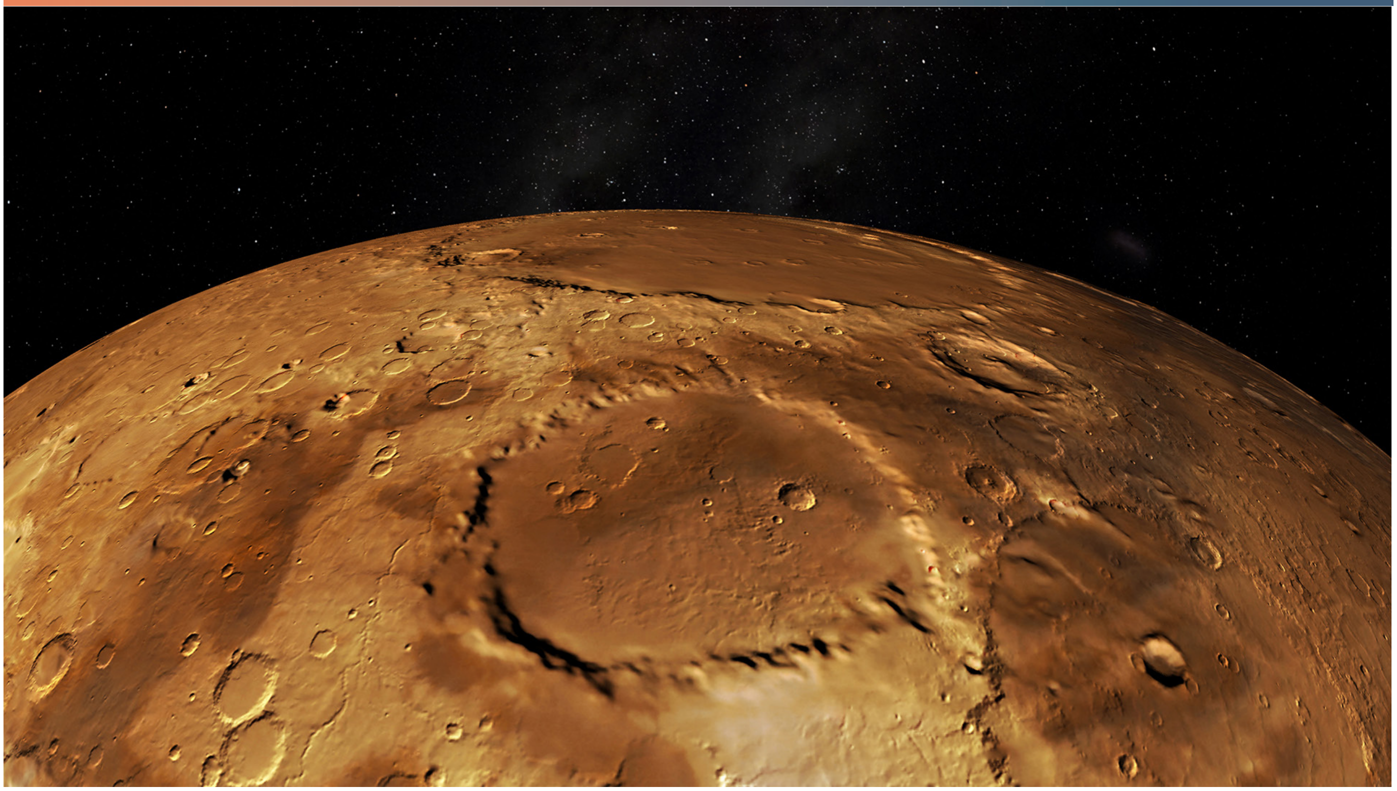
Microgravity: The very low gravity environment found in orbit around a solar system object. While it is commonly stated that there is no gravity in space, an astronaut or spacecraft in Earth (or Mars) orbit will actually experience very small amounts of pull toward the planet they are orbiting.

Orbiter: A spacecraft designed to enter orbit around a solar system object, such as a planet or asteroid, with no capability of making it to the surface.

Rover: A spacecraft designed to make it to the surface of a solar system object, such as a planet or asteroid, and then move around on the surface. The longest-lived rover on Mars, Opportunity, has traveled over 26 miles across the surface.

Solar Wind: A stream of charged particles, such as electrons, protons, and alpha particles, continuously emitted from the Sun's outer atmosphere. Since these particles have an electrical charge, they can be strongly effected by magnetic fields, such as that generated by the Earth's liquid iron core.





These websites are intended to provide access to further information about human space travel and the journey to Mars.

"Mars for Educators" Education and Outreach
mars.nasa.gov/participate/marsforeducators

NASA's Mars Exploration Program Webpage
mars.nasa.gov

Mars Trek Interactive Mars Map
marstrek.jpl.nasa.gov

International Space Station Webpage
nasa.gov/mission_pages/station/main/index.html

Exploration Mission-1 Webpage
nasa.gov/content/exploration-mission-1

Photo © Michael Malyszko

Your journey to the stars continues! With astronomy-related offerings located throughout the Museum's Exhibit Halls, you and your students can continue your extraterrestrial explorations for a day filled with the excitement of learning.

Cosmic Light Exhibit *Red Wing, Level 1, Outside Planetarium*

Explore concepts such as solar system relationships, the electromagnetic spectrum, and the scale of the universe.

To the Moon *Blue Wing, Lower Level*

Created in July 2009 in celebration of the 40th anniversary of the first Moon landing, this exhibit features full-size models of the Apollo and Mercury capsules and a graphic timeline documenting this significant era of human space exploration.
Free with Exhibit Halls admission.

The Light House *Blue Wing, Level 2*

Ranging from radio waves (larger than a football field) to gamma rays (a billion times smaller than a pinhead), wavelengths are all invisible to the human eye, except for the section of the spectrum known as visible light. In this exhibit, you can explore the science behind light and color. *Free with Exhibit Halls admission.*

Gilliland Observatory *Fridays, April – October; Hours Vary*

Enjoy stargazing at the Museum's rooftop observatory! The Gilliland Observatory is equipped with a computer-controlled Celestron CGE 1100 Schmidt Cassegrain telescope and is staffed by knowledgeable Museum employees.

Weather permitting. Please call the Gilliland Observatory hotline, 617-589-0267, which is updated at 5:30 p.m. on Friday nights with information about that night's observing session. Admittance is free thanks to the generosity of the Lowell Institute (parking charges still apply).

Earth & Space Exploration

Live Presentation, Approximately 20 Minutes, Check Schedule at mos.org/daily

Watch a demonstration on the changes happening on our planet, or explore the solar system and beyond with a presentation on the latest space missions.

Free with Exhibit Halls admission. Advance registration available for school groups (minimum 25 people). Email presentationrequests@mos.org at least two weeks prior with requested show title, date of visit, and number attending.

Live Planetarium Shows

Live Presentation, Approximately 40 Minutes, Check Schedule at mos.org/daily

Live shows are highly interactive, encouraging students to participate with a Planetarium educator as they learn about various topics in astronomy, earth science, and physics.

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